

**UNITED STATES PATENT APPLICATION**

**OF**

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**FOR**

**RETRACTABLE VACUUM TUBE FOR POSITIONING  
ELECTRONIC COMPONENTS ON PRINTED  
CIRCUIT BOARDS**

**Attorney Docket No. 018190-308  
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"Express Mail" mailing label No. EL 863876820US  
Date of Deposit: November 2, 2001

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Atty Dkt. No. 018190-308

## **Retractable Vacuum Tube for Positioning Electronic Components on Printed Circuit Boards**

### **Technical Field**

[0001] The present invention relates in general to optical positioning systems and in particular to heated gas soldering / desoldering systems for placing or removing integrated circuit chips from printed circuit boards.

### **Background of the Invention**

[0002] The fabrication of modern electronic components typically involves the attachment of electronic components such as integrated circuits onto printed circuit boards. Such integrated circuits are first positioned at the desired location on the circuit board and are then soldered by heated gasses into position. Such positioning and soldering operations require precise control for at least the following reasons.

[0003] Integrated circuit chips typically comprise an array of small balls or solder columns which extend downwardly from the back of the chip and/or small leads which extend downwardly from the perimeter of the chip. When assembling electronic systems, the various electronic components are sequentially placed onto a printed circuit board such that the leads extending downwardly therefrom are positioned at desired locations on the printed circuit board, and are then soldered into position. Typically, the placement of such electronic components are carried out by automatic positioning systems which lower the components into position.

[0004] Different electronic components have different thicknesses. Thicknesses vary not only among different types of electronic components, but also for each particular type of component. For example, modern integrated circuit chips may vary from as little as 0.5 mm to as much as 4.0 mm in thickness.

5 [0005] Accordingly, when positioning components of different thicknesses with an automated placement system, it is necessary to take the thicknesses of the components into account. This must be done such that the balls or leads extending from the bottom surfaces and sides of the components are positioned at the same height (i.e. in precise contact with the surface of the printed circuit board). For 10 example, if the integrated circuit chip is thick, the tool head need not travel as far down when positioning the integrated circuit chip on the printed circuit board. Conversely, if the integrated circuit chip is thin, the tool head need travel slightly farther down when positioning the leads of the integrated circuit chip on the printed circuit board.

15 [0006] Unfortunately, although existing component alignment and placement systems can be used to accurately visually position a component in X and Y directions, (i.e.: back and forth and side-to-side), above the printed circuit board, such alignment systems are not typically able to accurately visually position a component in the Z (i.e. vertical) direction. This is due to the fact that such 20 alignment systems rely on an optical positioning system which views a superimposed image of the component and the printed circuit board. Such an image permits alignment in the horizontal X and Y directions, but not in the vertical Z direction. Therefore, from such images, it is not possible to directly view the downward vertical (i.e. Z) distance which the tool head travels when 25 positioning the electronic component. Thus, the vertical (i.e.: Z) distance which the component positioning head travels when positioning the electronic component

travels must be separately pre-programmed into the placement system for each electronic component.

[0007] As can be appreciated, as progressively smaller and thinner integrated circuit chips, having more complex solder ball arrays are developed, it becomes  
5 more and more difficult to accurately position the integrated circuit chips on the surface of the printed circuit boards. For example, today's integrated circuit chips may have ball arrays as small as 1 mm<sup>2</sup>. Such ball arrays may have a "pitch" (i.e.: the distance between adjacent solder balls) as small as 0.3 mm. Thus, due to the small size of the individual balls in an array, accurately positioning the integrated  
10 circuit chip at the exact height so as not to damage such small elements of the chip requires a system which is capable of very accurate controlled vertical movement.

#### **Summary of the Invention:**

[0008] In preferred aspects, the present invention provides a system for positioning components of different thicknesses on a component platform, comprising: a frame; a tool head connected to the frame, the tool head being vertically movable; a retractable vacuum tube receivable within the tool head; and a grasping assembly which can be actuated to securely hold the vacuum tube in a fixed position relative to the tool head after the vacuum tube has been at least partially received within the tool head. Most preferably, the grasping assembly  
15 comprises a collet and bushing assembly within the tool head.  
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[0009] In other preferred aspects, the present invention provides a method of positioning a component on a target surface, comprising: positioning a tool head over the component, the tool head having a retractable vacuum tube extending downwardly therefrom; lowering the tool head until the vacuum tube contacts an

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upper surface of the component and is pushed into a retracted position within the tool head; securely holding the vacuum tube in a fixed position relative to the tool head after the vacuum tube has been pushed into the retracted position within the tool head; lifting the tool head, thereby lifting the component with the vacuum tube; positioning the tool head over the target surface; lowering the tool head such that a bottom surface of the component is positioned in contact with the target surface; and releasing the component from the vacuum tube. Most preferably, the vacuum tube is securely held in a fixed position relative to the tool head after the vacuum tube has been pushed into the retracted position within the tool head by moving a bushing on a collet assembly within the tool head.

[0010] In preferred aspects, the components comprise (but are not limited to) electronic components in general, and integrated circuit chips in particular. Also in preferred aspects, the component platform comprises a printed circuit board.

[0011] An advantage of the present invention is that it provides a system wherein electronic components of different thicknesses can easily be positioned on a printed circuit board. Specifically, this placement can be accomplished without regard to the exact thicknesses of each of the various electronic components by holding onto the components with a retractable vacuum tube. Rather, as each component is positioned on the printed circuit board, the tool head holding the component need only be moved downwardly the same distance regardless of the thickness of the component. This advantage is achieved by the vacuum tube holding the component retracting different distances into the tool head depending upon the thickness of the component which it is holding.

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[0012] A further advantage of the present system is that components can be picked for placement without the vacuum tube exerting too great a downward pressure on the component. Such pressure is to be avoided as it may damage the fragile solder ball array on the underside of the chip. This advantage is due to the  
5 fact that the present vacuum tube retracts into the tool head when picking up the component.

[0013] Thus, the present invention facilitates rapid component placement, thereby increasing overall assembly speed and efficiency.

**Brief Description of the Drawings:**

10 [0014] Fig. 1A is a perspective view of the present invention, with the optical system retracted, prior to component placement.

[0015] Fig. 1B is a perspective view of the present invention, with the optical system extended, prior to component placement.

15 [0016] Fig. 1C is a perspective view of the present invention, with the optical system retracted, at the time of component placement.

[0017] Fig. 2A is a side elevation view of the present invention, corresponding to Fig. 1A.

[0018] Fig. 2B is a side elevation view of the present invention, corresponding to Fig. 1B.

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[0019] Fig. 2C is a side elevation view of the present invention, corresponding to Fig. 1C.

[0020] Fig. 3A is a front elevation view of the present invention corresponding to Figs. 1A and 1B.

5 [0021] Fig. 3B is a front elevation view of the present invention corresponding to Fig. 1C.

[0022] Figs. 4A to 4C show sequential steps in picking up of an electronic component for placement, as follows.

10 [0023] Fig. 4A is side elevation view of the present invention prior to picking up the electronic component, showing a movable tool head (having a movable vacuum tube received therein) positioned over the electronic component.

[0024] Fig. 4B is a side elevation view showing the tool head of Fig. 4A after it has been lowered to pick up the electronic component.

15 [0025] Fig. 4C is a side elevation view showing the tool head of Fig. 4B after it has been raised, thereby lifting the electronic component.

[0026] Fig. 5A is a side-by-side comparison showing the present movable tool head positioned to lift electronic components of different thicknesses.

[0027] Fig. 5B is a side-by-side comparison showing the present movable tool head lifting electronic components of different thicknesses.

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[0028] Fig. 6A is an cross sectional view of the tool head of the present invention, showing the vacuum tube in an extended position.

[0029] Fig. 6B is an cross sectional view of the tool head of the present invention, showing the vacuum tube in a retracted position.

5      **Detailed Description of the Preferred Embodiments**

[0030] Referring to the attached Figs., the present system provides an alignment system 10 for positioning an electronic component 20 at a preferred (i.e.: target) location 31 on a printed circuit board 30 or other pad or substrate. Component 20 is held in position by a vacuum tube 26 extending downwardly from movable tool head 25. Similarly, printed circuit board 30 is held in position by a movable component platform 35.

[0031] Alignment system 10 comprises a frame 15 to which both tool head 25 and component platform 35 are attached. In accordance with the present invention, both tool head 25 and component platform 35 are separately positionable in X and Y directions.

[0032] In optional preferred aspects, vacuum tube 26 is rotatable about its longitudinal axis, thereby permitting component-to-board alignment in a further dimension (i.e.: component 20 can be rotated into a preferred position above component platform 30, prior to placement).

20     [0033] Electronic component 20 preferably comprises an integrated circuit chip having an array of ball solder leads 21 on its underside or edges. It is to be understood, however, that electronic component 20 is not limited only to

integrated circuit chip, but may instead comprise any sort of electrical or non-electrical component. Additionally, tool head 25 may preferably comprise a heated gas soldering / desoldering tool head, but also is not so limited. Rather, tool head 25 may comprise any sort of component positioning head or substance (e.g.: gel /glue) application head.

5 [0034] In accordance with the present invention, electronic component 20 is positioned at target location 31 on printed circuit board 30 using retractable optical system 40, as follows. Retractable optical system 40 is slidably movable between a "pushed in" or "retracted" position (as shown in Figs. 1A and 2A) and a "pulled 10 out" or "extended" position (as shown in Figs. 1B and 2B). As shown in Fig. 2B, retractable optical system 40 preferably comprises an internal camera 42 and a beam splitter 44 (shown in dotted lines).

15 [0035] Initially, prior to component placement, as shown in Figs. 1B and 2B, assembly 40 is "pulled out". At this time, camera 42 views an image through beam splitter 42 such that it simultaneously views leads 21 on component 20 and target area 31 on printed circuit board 30. With optical assembly 40 "pulled out", tool head 25 is then moved (in X and Y directions) such that component 20 is positioned roughly above target area 31. Such movement comprises a "coarse" - positioning.

20 [0036] Manual movement of tool head 25 in the X and Y directions is achieved as follows. Tool head 25 is slidably positionable along rods 27. Thus, tool head 25 may be slidably positioned side-to-side along rods 27 in the X direction. Similarly, positioning arms 29 are slidably movable along rods 28 such that arms 29 be slidably positioned back and forth in the Y direction. Such X and Y

movement of tool head 25 comprises "coarse" alignment of tool head 25 and target region 31. Preferably, as shown in Fig. 1A , the operator may push button 34 to unlock movement of tool head 25 (along rods 27), or may push button 37 to unlock movement of positioning arms 29 (along rods 28). Thus, tool head 25 is 5 preferably separately positionable in either of the X and Y directions (while movement in the other direction is prevented) by the operator depressing buttons 34 and 37 separately. This optional feature of the invention further assists in accurate component alignment as the tool head can be manually positioned first in the X direction, and then in the Y direction (or vice versa).

10 [0037] After positioning tool head 25, component platform 35 is then moved (in X and Y directions) such that printed circuit board 30 is then positioned in precise alignment with component 20. Such movement comprises "fine" positioning alignment. In preferred aspects, manually adjustable knobs 36 and 38 can be used to rotate fine positioning screws which move component platform 35. For 15 example, knob 36 can be used to move component platform 35 in the X direction and knob 38 can be used to move component platform 35 in the Y direction. The positioning screws which are rotated by knobs 36 and 38 preferably comprise "micrometer" adjustment screws. For example, in preferred aspects, a suitable pitch for such positioning screws ranges from 20 to 100 rotations per inch. In an 20 exemplary embodiment of the invention constructed by the Applicants, a positioning screw having a pitch of 48 turns per inch was used. Such micrometer scale screws permit precise X and Y directional alignment between component 20 and target region 31 to be accomplished manually. In an exemplary embodiment of the invention constructed by the Applicants, component platform 35 is 25 dimensioned large enough to handle a 8" by 10" printed circuit board 30. To achieve precise positional alignment, it was only necessary for component platform

35 to move printed circuit board 30 by small distances (specifically, on the order of plus or minus 1/4 inch).

[0038] As explained above, and as shown in Fig. 2B, camera 42 takes an image through beam splitter 44 which simultaneously shows the positions of component 5 20 and printed circuit board 30. After component 20 has been positioned in precise alignment with target region 31 of printed circuit board 30, optical system 40 is then retracted (i.e.: "pushed back in" to the position as was shown in Fig. 1A and 2A). Thereafter, as shown in Figs. 1C and 2C, tool head 25 is then lowered (i.e.: moved downwardly in the Z direction) such that component 20 is positioned 10 directly on printed circuit board 30. In preferred aspects, this downward movement is controlled by stepper motors such that precise Z directional movement is achieved. Precise mechanical lowering of tool head 25 thus ensures that component 20 is positioned at an appropriate height such that its leads 21 just touch printed circuit board 30.

15 [0039] At this time, heater 24 (which surrounds vacuum tube 26) emits a heated gas which heats component 20 such that its array of leads 21 solders into the preferred target location 31 on printed circuit board 30. In addition, heated gas is also passed upwardly through pre-heater 37 (positioned under component platform 35), thereby directly heating a lower surface the printed circuit board 30. An 20 advantage of heating printed circuit board 30 by pre-heater 37 heating its underside is that the board can be heated to a temperature just less than the melting point of the solder. Accordingly, only a small amount of heat needs to be applied from above component 20 through heater 24 in tool head 25 to solder electronic component 20 into position. In the absence of heat applied upwardly through pre- 25 heater 37 under component platform 35, it would be necessary to apply much

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more heat with tool head 25 alone. Unfortunately, this may tend to increase thermal shock to the board, causing localized heating, thereby warping the circuit board.

[0040] Figs. 4A to 4C show the successive steps of picking an electronic component up from a first location (such as a component tray). Thereafter, the electronic component can be positioned on a component platform or structure disposed on a component platform (such as a printed circuit board).

[0041] Referring first to Fig. 4A, tool head 25 is shown positioned above electronic component 20. Component 20 is shown positioned on surface 50. Surface 50 may represent any sort of surface on which components are initially provided. For example, surface 50 may represent a tray containing a plurality of similar electrical components which are to be attached to printed circuit boards. Tool head 25 is lowered to the position shown in Fig. 4B in which vacuum tube 26 contacts with, and holds onto component 20. In accordance with the present invention, vacuum tube 26 is at least partially slidably retractable into tool head 25. Therefore, as tool head 25 is moved downwardly to its final lowered position as shown in Fig. 4B, vacuum tube 26 is at least partially retracted into tool head. By retracting, vacuum tube 26 advantageously avoids downward pushing of component 20 when picking up the component. Such downward pushing on the top of the component may tend to damage the fragile solder balls or leads extending downwardly from the bottom surface of the component.

[0042] After vacuum tube 26 has been retracted, (i.e. when downward movement of tool head 25 stops), vacuum tube 26 is then locked into position such that it does not move within tool head 25. As will be explained herebelow, vacuum

tube 26 can be held in a fixed position within tool head 25 by a collet assembly. It is to be understood, however, that the present invention encompasses any suitable system for holding vacuum tube 26 in a fixed position within tool head 25.

[0043] As shown in Fig. 4C, after vacuum tube 26 is secured in a fixed position within tool head 25, tool head 25 can then be raised by distance D1, such that it lifts electronic component 20 by a distance D1 away from surface 50. Thereafter, tool head 25 can be positioned over a target location on a component platform. Such positioning can be accomplished by moving the tool head, moving the component platform, or more preferably, by moving both.

[0044] Thereafter, tool head 25 can then be lowered into a position (similar to Fig. 4A) such that component 20 is placed directly on top of the printed circuit board 30 (which is held in place by a component platform 35). At this time, component 20 is released by vacuum tube 26, and tool head 25 is then used to solder component 20 into position the component platform 30.

[0045] An important advantage of the present invention is that it can be used to easily grasp onto components of different thicknesses, and then accurately position these components on a printed circuit board (or other surface or platform) without regard to the thickness of the individual component, as follows.

[0046] Referring to Figs. 5A and 5B, tool head 25 is shown picking up components of different thicknesses (e.g.: a thin component 20A and a thick component 20B). Thus, Fig. 5A illustrates the same step shown in Fig. 4B. (i.e. when tool head 25 has been lowered into the position such that its vacuum tube 26 latches onto and thereby picks up component 20. Similarly, Fig. 5B illustrates the

same step shown in Fig. 4C (i.e. when tool head 25 has been raised, thereby lifting the component.

[0047] As was explained, tool head 25 is preferably lowered a distance sufficient such that vacuum tube 26 is at least partially retracted within tool head 25 when 5 component 20 is initially picked up. As shown in Fig. 5A, when tool head 25 has been positioned to lift a thinner component 20A, vacuum tube 26 will be received only a short distance into tool head 25. Conversely, when tool head 25 has been positioned to lift a thicker component 20B, vacuum tube 26 will be retracted farther into tool head 25. This is particularly advantageous, as follows.

10 [0048] After vacuum tube 26 has grasped onto component (20A or 20B), vacuum tube 26 will then be locked into position (such that it doesn't move relative to tool head 25). At this time, tool head 25 is raised by distance D1 (Fig. 5B). As can be seen, such lifting results in either of component 20A or 20B being lifted to a position such that their bottom surfaces (and their leads 21 extending therefrom) 15 are held at the same height (D1) above surface 50.

[0049] Accordingly, when positioning either of components 20A or 20B on a component platform 30 or other surface, it is only necessary to lower the tool head the same distance (D1) such that the leads 21 of the respective component (20A or 20B) will be placed into direct contact on top of the component platform. For 20 example, if surface 50 is positioned at the same height as printed circuit board 20, it is only necessary to lower tool head by the same distance D1 when positioning leads 21 of the respective component (20A or 20B) on printed circuit board 20. Thus, thick or thin components can be lowered exactly the same distance when being placed on the surface of a printed circuit board.

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[0050] As explained herein, vacuum tube 26 is preferably received at least partially within tool head 25 after vacuum tube 26 contacts an upper surface of component 20 when tool head 25 is first lowered into position to pick up the component.

5 [0051] In accordance with the present invention, an exemplary system for securely locking vacuum tube 26 in a fixed position within tool head 25 is provided. Referring to Figs. 6A and 6B, a movable bushing and collet assembly 60 is provided. Fig. 6A illustrates vacuum tube 26 in an extended position. After the tool head 25 of Fig. 6A has been lowered into position (with vacuum tube 26 10 grasping onto a component 20 (not shown), vacuum tube 26 will be pushed by distance D2 upwardly into tool head 25.

15 [0052] As shown in Fig. 6B, after vacuum tube 26 is retracted, bushing 61 (which is preferably spring biased) moves upwardly so as to pinch together collet fingers 61, thereby holding vacuum tube 26 in a fixed position. Collet know 63 preferably protrudes out of the front of tool head 25 such that an operator can simply manually rotate vacuum tube 26 by rotating knob 63. Thus, a further advantage of the present assembly is that component 20 can be manually rotated (about an axis extending longitudinally through vacuum tube 26) into a preferred alignment for placement on component platform 30. (See knob 63 in Fig. 1A).

20 [0053] Fig. 6A shows bushing 61 pushed downwardly such that collet fingers 62 do not "pinch" against vacuum tube 26, and thus restrict its motion.

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[0054] A further advantage of this system is that when the present invention senses that vacuum tube 26 has started to retract, it knows that contact has been made with component 20.